The Director's Proton Team: A Status Report for the PAC
(Proton Source Committee Interim Report)

- Proton Team Workings
  - Charge and Membership
  - Schedule (of the Team's workings)
  - Assignments and Interviews
- Beam Demands, Realistic Goals
- Linac, Booster, Main Injector
- Modifications, Collaboration, Organization

Charge

(Witherell to Finley 2/19/03)

- 1) Identify users of protons over the period 2003-2010 and the demands represented by each.
- 2) Establish technical goals for delivery of protons, both from the Booster and Main Injector, over the period.
- 3) Identify major modifications to the Proton Source and Main Injector that will be required to meet these goals assuming availability of Fermilab resources at the few x $10M level over the period.
- 4) Identify possible resources and opportunities for collaboration by institutions outside Fermilab.

5) Suggest an organization for implementing a program of modifications, including opportunities for integration of collaborators outside Fermilab.

Chair's Direction at Initial Meeting

- This is what I think we are doing:
  - Gather the information into one place and present it to the Director.
  - Finish ASAP so that management can get on with directing the resources where they are needed.

A Couple of the Chair's Ground Rules

- I do not want to halt ongoing activities, so let us hear first from:
  - Eric Prebys: Ongoing activities in Booster
  - Shekhar Mishra: Ongoing activities in MI … and Greg Bock's plans (Greg is the NuMI project manager)
- We will not defer to a "New Proton Source" as the solution.
  - But its possibility will likely influence our thinking as we come up with modifications for the Linac and Booster (at least).

Membership

• David Finley	Chair
• Janet Conrad	Co-spokesperson of MiniBooNE
• Doug Michael	Co-spokesperson of MINOS
• Chuck Ankenbrandt	Booster and Beam Physics
• Peter Kasper	Booster
• Alberto Marchionni	Main Injector Beam
• Eric Prebys	Head of Booster
• Shekhar Mishra	Head of Main Injector
• Greg Bock*	NuMI Project Leader
• Ray Stefanski	Secretary

*Note: Greg Bock has a standing conflict

Honorary Membership

- Some Contacts and Kibitzers
  - Greg Bock — NuMI Project Leader
  - Elliott McCrory — Head of Proton Source
  - Roger Dixon — Head of Beams Division
  - Mike Church — Deputy Head of Beams Division
  - Steve Holmes — Associate Director for Accelerators
  - Hugh Montgomery — Associate Director for Physics
  - Jeff Appel — Head of Program Planning

These people and many others will be “interviewed” for their input.

Membership
(with "party affiliation")

• David Finley	Chair	MiniBooNE
• Janet Conrad	co-spokesperson of	MiniBooNE
• Doug Michael	co-spokesperson of	MINOS
• Chuck Ankenbrandt	Booster Beam Physics	-----
• Peter Kasper	Booster	MiniBooNE
• Alberto Marchionni	Main Injector Beam	MINOS
• Eric Prebys	Head of Booster	MiniBooNE
• Shekhar Mishra	Head of Main Injector	-----
• Greg Bock	NuMI Project Leader	MINOS
• Ray Stefanski	Secretary	MiniBooNE

Schedule

(as seen on March 23, 2003)

- Weekly: Noon or 1130AM to 130PM
  - Initial meeting 2/20/03
  - We post to the web as much as possible for these meetings because we use phone links (and video is available if necessary)
  - Chair makes assignments and Members report on assignments
- Timeline
  - March 13: 1st Witherell Briefing (only time for 1st half of committee)
  - March 29: Chair briefs Physics Advisory Committee
  - April 3: 2nd Witherell Briefing (2nd half of committee)
  - May 1 Draft Written Report (in Word)
  - ~ June 1 Final Written Report
  - ~ June 15 Aspen PAC Briefing (if necessary, but I'd rather it come from management … we'll see.).

Assignments: Beam Demands & Goals

- Primary / Helpers
  - Linac: Finley / Ankenbrandt, McCrory
    - Booster, NTF, MUCOOL, Studies …
  - Booster: Prebys / Kasper, Conrad, Ankenbrandt
    - MiniBooNE, Main Injector, Radiation Facility, Studies …
  - Main Injector: Mishra / Marchionni, Michael
    - Run II, NuMI, SY120, Studies …

Interviews on March 20 Agenda

- 3a. Many: Reports from Interviews: (~40 minutes?)
- i. Dave on Jeff Spalding - 5
- ii. Alberto on SY120 (Chuck Brown, Raja Rajendran etc) - 10
- iii. Janet and Peter on Peter Cooper - 5
- iv. Dave on Craig Moore - 5
- v. Janet on Jeff Appel - <5?
- vi. Janet and Doug on Hugh Montgomery <5?
- vii. Dave on Mike Church - 5
- viii. ”Dave on Panagiotis Spentzouris – 5”
- ix. ”Dave and Doug on Roger Dixon <5?”
  - Note: Items in quotes didn’t happen by March 20

Yet to Be Interviewed (as of March 20)

- Ioanis Kourbanis: All things Main Injector, especially longitudinal
- Paul Czarapata: Linac Tubes
- Bill Foster: All things … in particular dampers
- Greg Bock: NuMI project plans
- Nancy Grossman: NuMI ground water limits
- Mary Anne Cummings: MUCOOL revisited
- Weiren Chou: Space Charge
- Panagiotis Spentzouris: Space Charge
- Francois Ostiguy: Collaborations
- Steve Holmes: Missing Information
- Etc etc etc including follow-up interviews as necessary

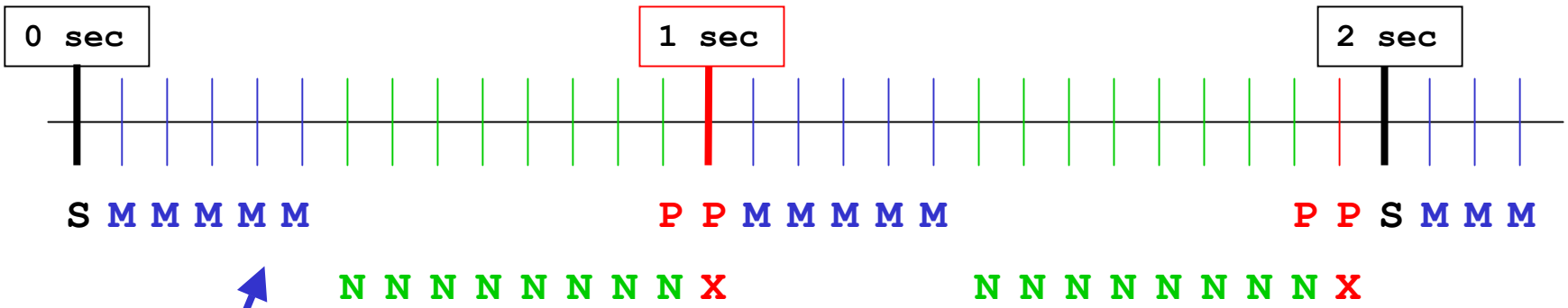
Linac Beam Demands and Goals

- Linac beam demands are characterized by use of the 15 Hz cycles (or percent of time), not by intensity
- Primary Demands
  - 1 (today) to 2 cycles / 2 seconds for Stacking (0.5 to 1 Hz)
  - 3 (today) to 5 Hz maximum to MiniBooNE
  - ~5 cycles / 2 seconds for NuMI ("baseline" ~2.5 Hz)
- Secondary Demands
  - ~3% MUCOOL; ~1.8% NTF; ~1% Beam Maintenance
- The peak for 400 MeV Linac beam pulses ever for a 24 hour period started on 21FEB03 0100 … 18.3%.
- The baseline Primary Demands are (1+5+2.5)/15 = 56.6%

"Today's" Linac Demands: Stacking, MiniBooNE & NTF

(Linac Timeline provided by E. McCrory; edited by D. Finley)

With 2 second Main Injector cycle (30 Linac cycles)



Dear Editor: One "tick" and "N" needs to be added in this second

User	Pulses	Rate
Stacking	1	0.5 Hz
MiniBooNE	10	5 Hz
NTF	17	8.5 Hz
No Beam	2	1 Hz

Note: Today's real MiniBooNE is closer to 3 Hz.

Linac at a Glance

- Radiation Limitations (no real limit before 2010)
  - At the moment most of Linac galleries are unlimited occupancy. This may need to be changed to limited occupancy as the number of 400 MeV cycles is increased with NuMI + Run II plus MiniBooNE plus …
- The 7.5 Hz Booster limits the 400 MeV Linac beam
  - Also, at the moment there is a vestige of the Main Ring buried in the Proton Source which prevents more than 13 linac cycles in a row of beam destined for 8 GeV. It can be removed.
- The Linac is capable of delivering:
  - Run II and MiniBooNE and NuMI and NTF and MUCOOL and Beam Maintenance … not a technical problem.
  - Unless it runs out of RF tubes …Then a HUGE CRISIS!
- The Linac can run better with modifications.

Some Issues (as seen by Chair on 2/20/03)

- Running MiniBooNE and NuMI contemporaneously
  - **con·tem·po·ra·ne·ous** *adj.* Originating, existing, or happening during the same period of time as in *the contemporaneous reigns of two monarchs.*

Not as big a technical deal as first thought … but NuMI & Stacking and incorporating SY120 are big deals.

- Administration of controlled vs. uncontrolled losses
- Intensity and/or scheduling
  - "$$$, people, time" and/or Program Planning
  - Linac and SY120 are scheduling (I suspect)
  - NuMI, MiniBooNE, Run II are Intensity

Too simplistic …

- Better radiation protection for worker doing maintenance
- And …Linac RF tubes, Linac radiation limits? …

Model for Booster Beam Demands

(Program by Peter Kasper, numbers by D. Finley) for "Now"

Program Requests "Now"							
Pbar	4.5E+19	p/year	4.54E+19	is 4.8E12 /2 sec MI cycle for 0.60 year			
NuMI	0.0E+00	p/year					
BooNE	1.6E+20	p/year	10	batches @	5	Hz	
CKM	0.0E+00	p/year	5.0E+12	p/second	6	sec slow spill	

Up Time (fraction of year)		1.6E20/year = 3E16/hr for 60% of the year
Booster	0.65	
MI	0.6	

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 [1]	Booster Rate (Hz) 7.5 [2]	Booster protons/hr 1.8E+17 [3]
BooNE	5	0.05	2.00	3.1E+12	3.50	2.8E+16
BooNE	5	0.60	2.00	3.1E+12	4.00	3.7E+16
NuMI	0			0.0E+00		
Pbar	1			4.8E+12		
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00
CKM	0			0.0E+00		

1) Booster losses grow dramatically above 5e12 p/batch

2) Booster hardware is limited to 7.5 Hz rep rate

3) Booster Shielding Assessment is good for 1.8E17 p/hr

Model for Booster Beam Demands

(Program by Peter Kasper, numbers by D. Finley) for "Now"

Program Requests "Now"							
Pbar	4.5E+19	p/year	4.54E+19	is 4.8E12 /2 sec MI cycle for 0.60 year			
NuMI	0.0E+00	p/year					
BooNE	1.6E+20	p/year	10	batches @	5	Hz	
CKM	0.0E+00	p/year	5.0E+12	p/second	6	sec slow spill	

Up Time (fraction of year)	
Booster	0.65
MI	0.6

1.6E20/year = 3E16/hr for 60% of the year

Presently limited by administrative control of residual radiation in the tunnel on high maintenance equipment.

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 1	Booster Rate (Hz) 7.5 2	Booster protons/hr 1.8E+17 3
BooNE	5	0.05	2.00	3.1E+12	3.50	2.8E+16
BooNE	5	0.60	2.00	3.1E+12	4.00	3.7E+16
NuMI	0			0.0E+00		
Pbar	1			4.8E+12		
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00
CKM	0			0.0E+00		

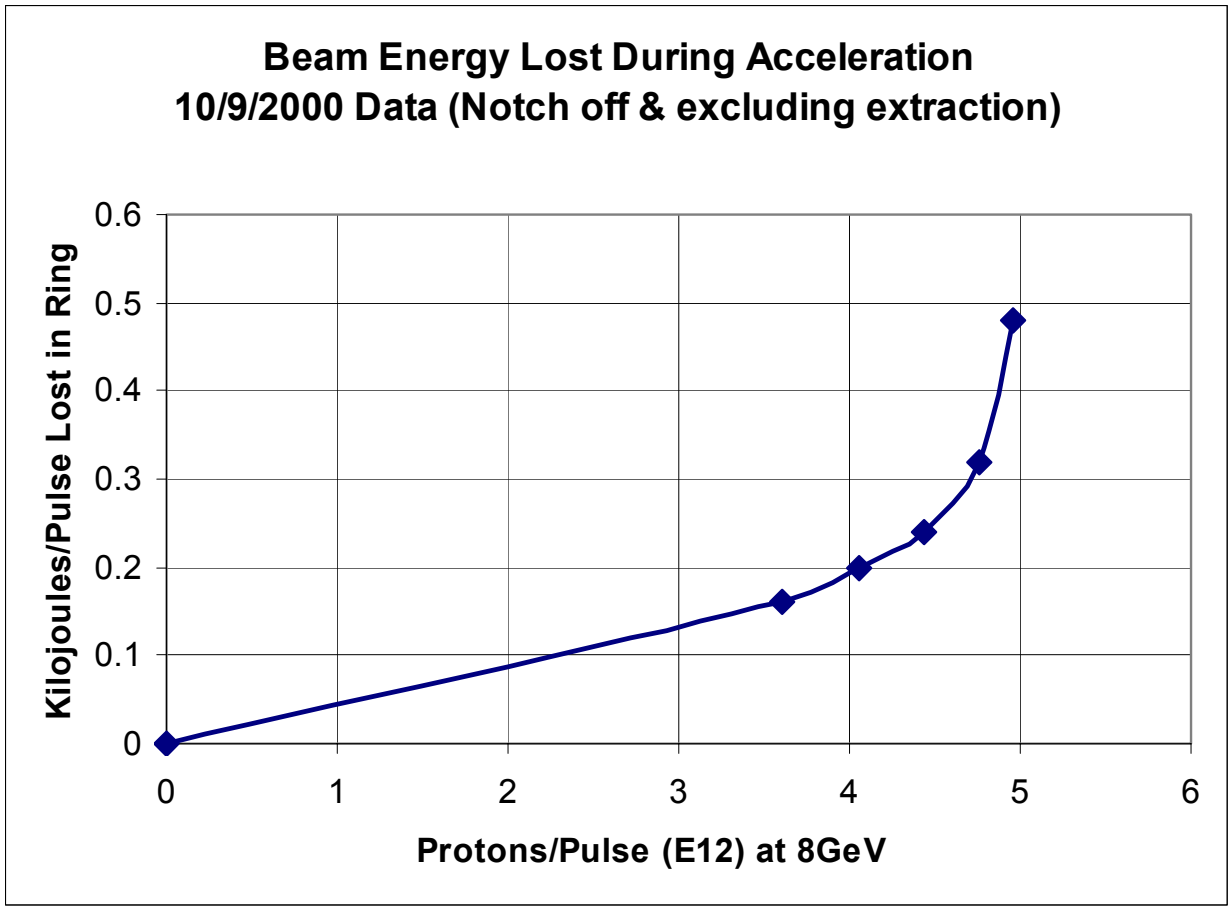
Well below the above ground shielding assessment limit

1) Booster losses grow dramatically above 5e12 p/batch

2) Booster hardware is limited to 7.5 Hz rep rate

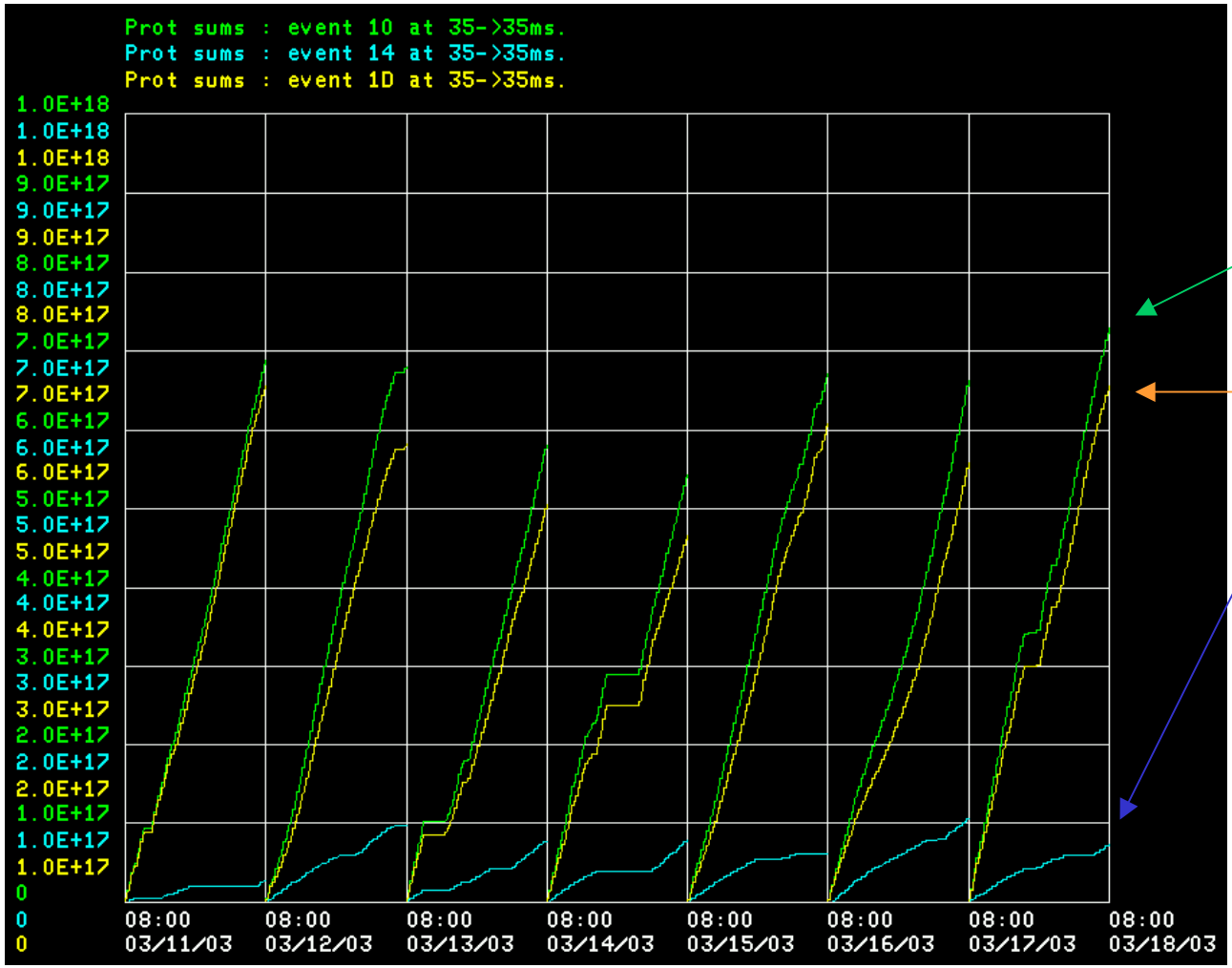
3) Booster Shielding Assessment is good for 1.8E17 p/hr

Beam Loss Intensity Sensitivity
(from Eric Prebys's Seminar March 18, 2003)



Where do Booster Protons Go Now?

(from Eric Prebys's Seminar March 18, 2003)



Total

MiniBooNE

Pbar production
(limited by debuncher)

Operationally, the collider gets whatever it wants, and MiniBooNE gets whatever is leftover within the limits

Booster Demand Model at "NuMI Turn On" (JAN05)

Program Requests "5E12"				aka "NuMI Turn On"		
Pbar	7.6E+19	p/year				
NuMI	2.3E+20	p/year	2.29E+20	is 5 x 5E12 / 2.07 MI cycle for 0.6 year		
BooNE	4.3E+20	p/year	10	batches @	5	Hz
CKM	0.0E+00	p/year	5.0E+12	p/second	6	sec slow spill
			4.3E20 / year is chosen to make BooNE batches = 5E12			

Up Time (fraction of year)	
Booster	0.8
MI	0.6

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 1	Booster Rate (Hz) 7.5 2	Booster protons/hr 1.8E+17 3
BooNE	10	0.20	2.00	5.0E+12	6.00	9.0E+16
BooNE	6	0.60	2.07	5.0E+12	7.26	1.1E+17
NuMI	5			5.0E+12		
Pbar	2			4.1E+12		
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00
CKM	0			0.0E+00		

Booster Demand Model at "NuMI Turn On" (JAN05)

Should we stop at 5E12?

Program Requests "5E12"				aka "NuMI Turn On"		
Pbar	7.6E+19	p/year				
NuMI	2.3E+20	p/year	2.29E+20	is 5 x 5E12 / 2.07 MI cycle for 0.6 year		
BooNE	4.3E+20	p/year	10	batches @	5	Hz
CKM	0.0E+00	p/year	5.0E+12	p/second	6	sec slow spill
			4.3E20 / year is chosen to make BooNE batches = 5E12			

Up Time (fraction of year)	
Booster	0.8
MI	0.6

Multi batch injection must work

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 1	Booster Rate (Hz) 7.5 2	Booster protons/hr 1.8E+17 3
BooNE	10	0.20	2.00	5.0E+12	6.00	9.0E+16
BooNE	6	0.60	2.07	5.0E+12	7.26	1.1E+17
NuMI	5			5.0E+12		
Pbar	2			4.1E+12		
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00
CKM	0			0.0E+00		

Proton Slip stacking must work.

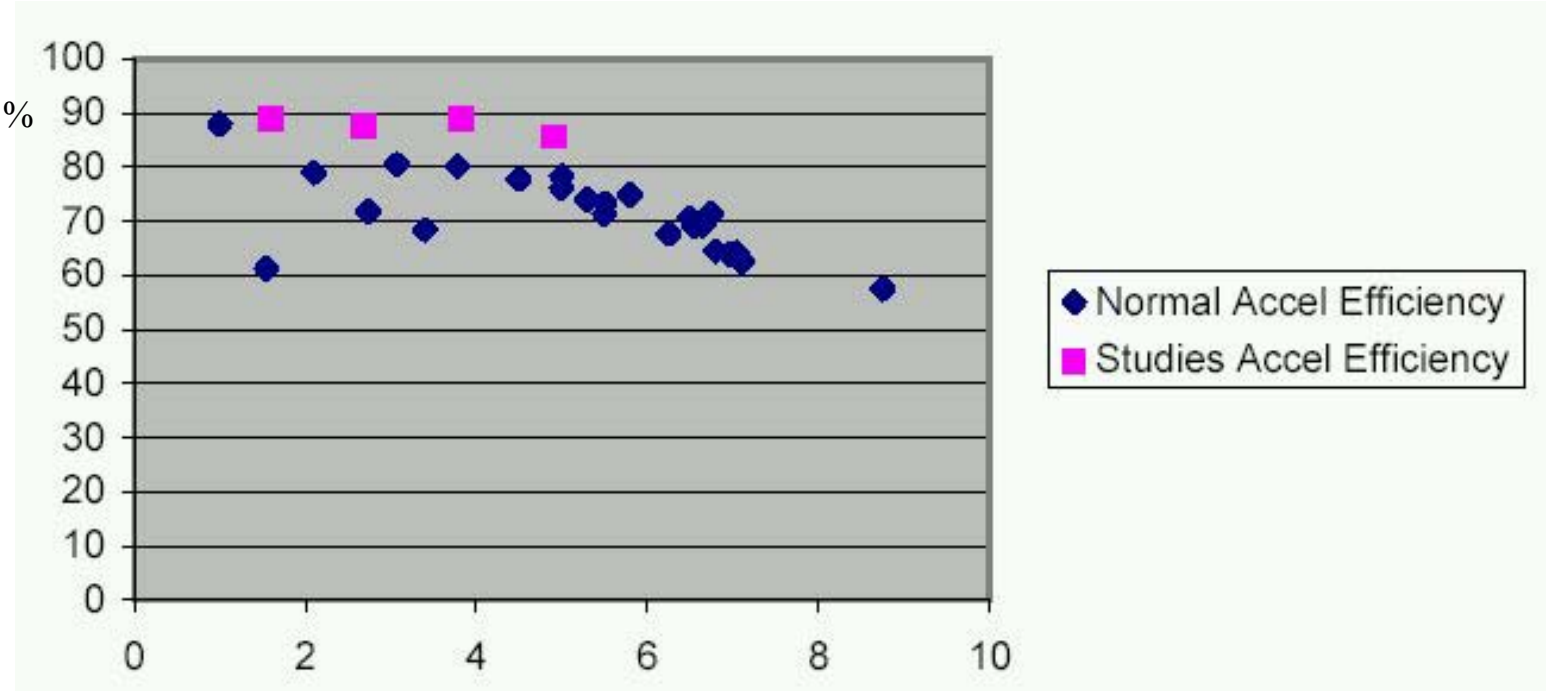
Booster Modifications at a Glance
(edited by DF from Eric Prebys's Seminar March 18, 2003)

* See next slide

- Ongoing or just starting
  - Simulations and Studies*, Collimation system, 2 larger aperture RF cavities, Improved injection magnet system (ORBUMPs) …
- Awaiting Decision/Priority or Better Idea
  - Improved extraction magnet system*, Remaining larger aperture RF cavities, New RF power supplies, Lower loss notching, Larger aperture magnets, Pulsed extraction magnets, Better radiation protection during maintenance, Better understanding of radiation damage limitations, Reliability and longevity …
- Note This Unsolved Problem (aka Cogging):
  - Acceptably controlled Booster losses and multibatch injection into the Main Injector are required for Run II Stacking, NuMI and (maybe) SY120. There is no well understood scheme being implemented for doing this yet.

A Study of Booster Extraction Magnets

(from Eric Prebys's Seminar March 18, 2003)



In the 3E12 to 5E12 Range, the beam loss plummets from about 25% to about 10%. This is a big deal!

Some Cold Hard Facts about the Future

(EDITED from Eric Prebys's Seminar March 18, 2003)

ten

1.8E20

- Running as we are now, the Booster can deliver a little over ~~1E20~~ protons per year – this is about a factor of ~~six~~ over typical stacking operations, and gives MiniBooNE about ~~20%~~ of their baseline.

33%

- NuMI will come on line in 2005, initially wanting about half of MiniBooNE's rate, but hoping to increase their capacity – through Main Injector Improvements – *until it is equal to MiniBooNE.*
- Whatever the lab's official policy, there will be great pressure (and good physics arguments) for running MiniBooNE and NuMI *at the same time*.
- -> By 2006 or so, the Proton Source might be called upon to deliver

6 → ~~10~~ times what it is delivering now.

- *At the moment, there is no plan for assuring this, short of a complete replacement*!
- But … No matter what, it is in Fermilab's interest to supply the hottest proton beam it possibly can.

Main Injector Goals & Modifications - 1

(Summarized from Shekhar Mishra's first presentations)

- Simultaneous Stacking for Pbar @ 8E12 and NuMI @ 2.5E13 requires:
  - Foundation: Operational coexistence of both, Proton Stacking in the Main Injector (also known as Slip stacking for Pbar), Longitudinal and transverse dampers, Beam permit system for NuMI, High intensity (today is < 2E13) development …
  - Improvements: Development of Slip stacking or Barrier bucket stacking for NuMI, and Faster cycle time

Main Injector Goals & Modifications - 2

(Summarized from Shekhar Mishra's first presentations)

- Tevatron 330E9 ppb, < 20 pi, < 2.5 eV-sec
  - Dampers, shorter shot setup times
- SY120: Possible Range: 1E9/sec to 6x5E12/6sec
  - Generate and control debunched beam, establish operational resonant extraction with multi-second flattop, control losses, E907 coming on line …
- Operate all in the same time period(?) … "all" = Stacking &Tevatron, SY120, NuMI

The August 5, 2002 Report (NuMI and the Main Injector & Booster)

This AUG02 report is one of our inputs. Although 3 of the 10 authors are on the team, it is apparent there is no consensus at the present on what to do.

Summary of					
"Accelerator Improvement Options for NuMI Proton Intensity"					
Released August 5, 2002					
Year	Potential				
	NuMI	Booster	Booster	MI	
	ppy	ppp	Rate	"cycle"	
	E20	E12	Hz	sec	
2002	1.6	4.5		2.46	
2003	2.4	5.0	7	1.9	
2004	2.6	5.5	8		
2005	3.9	6.0	11	1.7	
2006	4.9		13		
2007	5.1		15	1.0	
2008	6.0				

Annual steps are based on:

- Multi-batches and Proton Stacking in the Main Injector
- More Protons/Booster cycle
- Faster Main Injector cycle

The report is consistent but it makes some assumptions which might not be made today. (e.g. 2 sec Pbar cycle).

More Improvements in the 5AUG02 Report (but not in Shekhar's first presentations to the Team)

- Booster
  - New RF damping, Extraction of halo, Inductive inserts, RF to stretch bunches in time, Reliable 15 Hz RF …
- Main Injector
  - 3 Categories: Proton Stacking & Multibatch operation, *More protons per Booster cycle*, Decreased cycle time
  - More RF power and control, Collimator system, "New" RF cavities and more magnet power …

These plus all the other ones are about $26M x ~1.5

Same as a "few $10M level"?

1 Main Injector … 3 Physics Programs

- It's all about time … after all the technical problems for intensity are solved ...
  - On the one hand, SY120 experiments need a flattop at 120 GeV in the Main Injector during which time beam is extracted "slowly". Flattops ranging from 1 to 6 seconds are being discussed.
  - On the other hand, 120 GeV beam is extracted for "Stacking for Pbar" by kicking the required beam out in less than one turn of the Main Injector. One turn is about 11 microseconds. Same for NuMI. (Plus a little "preparation time".)
  - The Point: If the Main Injector is at 120 GeV, it cannot go down to 8 GeV so more beam can be injected into it.

1 Main Injector … 3 Physics Programs

- In my opinion (at this time) the best operational arrangement might be (as suggested by others):
  - Have Multiple Main Injector cycles one after the other with both NuMI and "Stacking for Pbar" coexisting in the same cycles.
  - A separate Main Injector cycle for SY120.
  - Intersperse these inside a minute according to priority. It is clear that no single program gets a Snowmass year of seconds in a real year this way.

Modifications, Collaboration, Organization

- Modifications
  - The Linac needs minimal modifications
  - The Booster is implementing some modifications
  - The Main Injector has begun planning for 3 programs
    - This situation is changing as we meet …
- Collaboration
  - Not addressed yet in the committee in any detail.
- Organization
  - Not started yet in the committee… but Fermilab DOES have the Director's Office, the Beams and Technical Divisions, real and potential collaborators, and "organizers" and people who can be "organized".

A Bit Of Philosophy on Setting Goals.

(The Chair's perspective … not yet cleared by the Team)

- I've noticed two bad methods for setting goals:
  - Set them high and when they are not achieved you can chalk it up to experience … but you hope you end up with more than you would have if you had set them lower.
  - Set them low so that you always achieve them … although you might miss opportunities that come along which would have allowed you to achieve more.
- Avoid extreme application of either method.

Summary: About Half Done

- Charge and Membership OK (with interviews)
- Schedule (of the Committee's workings) "OK"
- Assignments and Interviews Ongoing
- Issues: Recognizing Demands and Goals Ongoing
  - Recognizing them is one thing …
  - Putting down a realistic plan is another thing.
- Modifications, Collaboration, Organization
  - Various states of completion

Appropriate Quote of the Day

"Plans are useless, but planning is essential."

- Dwight David Eisenhower (perhaps) … but applicable to Fermilab's physics program

Backup

A Few Comments from People Upon Seeing the Membership

- "There is no one from Run II on it, and that is the Lab's highest priority."
- "Only two experiments are represented, and mine is not one of them."
- "You need someone from external beams."

Backup

My Responses to the Comments - 1

- When the committee was formed, it was thought that NuMI and MiniBooNE could not run at the same time for technical reasons, and sorting this out was thought to be a major issue.
  - Thus, co-spokespersons from MiniBooNE and MINOS were put on it, along with beam experts and the beams people who will carry out the modifications … with the hope all would arrive at a consistent vision.
  - Since then, it has become apparent (to me at least) that this need not be a technical issue (given resources of course).

Backup

My Responses to the Comments - 2

- However, NuMI will be a scheduling issue for Program Planning since it shares the Main Injector with Switchyard 120 (SY120) and with Stacking for Pbar.
  - SY120 demands slow resonant extraction requiring a one to six second flattop, and this simply (and literally) takes time which cannot be used by NuMI or Stacking for Pbar, and vice versa.
  - Stacking for Pbar (in today's Run II planning) requires 2 seconds between extractions. This prevents the Main Injector from implementing technically possible decreases in its cycle (given resources of course) which could benefit NuMI.

Backup

My Responses to the Comments - 3

- The Chair still thinks he can adequately represent Run II (given enough good advice). And this particular chair - after discussions with the 2nd floor - has taken the view he does not have a conflict of interest by being on MiniBooNE.
- The Chair now recognizes if the team were reinvented today, it would not have the same membership.
  - But that's why the members are supposed to interview people, and why the draft report will be read by some non-Members.
  - For example, I'd add Jeff Appel (he who will juggle experiments for a living) and Craig Moore (extraction and beam lines) and Ioanis Kourbanis (Main Injector strong man and RF gymnast) and drop one or more others so the committee does not get too big. (Is it already too big?)

Backup

Booster Demand Model
Some Additional Constraints …

Here is some of the "hidden wiring" in Kasper's model …

Only included in case of detailed questions …

Machine Parameters	
22	clicks for MI acceleration
2	clicks for slip-stacking (used if Pbar batches > 1 or NuMI+Pbar batches > 6)
1	click added to MI cycle for debunching for CKM
2	Booster prepulses required before beam cycles
2	seconds minimum MI cycle time for Pbar
Constants	
6.67E-02	seconds per Booster cycle = 1/15 second
3.2E+07	seconds per year

Backup

Booster Demand Model for "What's Needed Next (also known as ASAP"

Program Requests "Next"							
Pbar	7.6E+19	p/year	7.57E+19	is 2x4E12 / 2 sec MI cycle for 0.60 year			
NuMI	0.0E+00	p/year					
BooNE	5.0E+20	p/year	10	batches @	5	Hz	
CKM	0.0E+00	p/year	5.0E+12	p/second	6	sec slow spill	
			5E20 protons / year is MiniBooNE Goal/Demand				
Up Time (fraction of year)							
Booster	0.8		Note Separation of Booster and MI Operation				
MI	0.6						

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 1	Booster Rate (Hz) 7.5 2	Booster protons/hr 1.8E+17 3	
BooNE	10	0.20	2.00	4.0E+12	6.00	7.1E+16	
BooNE	10	0.60	2.00	4.0E+12	7.00	8.6E+16	Note BooNE Batch increase
NuMI	0			0.0E+00			
Pbar	2			4.0E+12			Note Slip Stacking for Pbar
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00	
CKM	0			0.0E+00			

Booster Demand Model for "More for Neutrinos" … But …

Backup

Program Requests "10Hz"		
Pbar	7.6E+19	p/year
NuMI	3.3E+20	p/year
BooNE	5.0E+20	p/year
CKM	0.0E+00	p/year

aka "Turn Up the Neutrinos"

3.3E20 is chosen to make NuMI batches = 5E12

10	batches @	5	Hz
5.0E+12	p/second	6	sec slow spill

Up Time (fraction of year)	
Booster	0.8
MI	0.6

Program	Booster Batches	Fraction of year allocated	Cycle time (sec)	Booster protons/batch 5.0E+12 1	Booster Rate (Hz) 7.5 2	Booster protons/hr 1.8E+17 3
BooNE	10	0.20	2.00	4.3E+12	6.00	7.8E+16
BooNE	10	0.60	2.27	4.3E+12	9.71 !	1.5E+17
NuMI	8			5.0E+12		
Pbar	2			4.5E+12		
BooNE	0	0.00	0.00	0.0E+00	0.00	0.0E+00
CKM	0			0.0E+00		

Note! > 7.5 Hz

Note: Note MI cycle > 2 sec to accommodate 3 additional NuMI batches >>> Subsequently the Batch requirement for Pbar increases to keep the Pbar yearly total the same … Caution: The MI cycle will be longer to combine the 8 NuMI batches into 4 …